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DEHYDRATED SOUPS FOR USAF AIRCRAFT

by
Harold Gorfien
Abdul R. Rahman
Edmund M. Powers
and
Donald E. Westcott

Project reference: 1G762713A04

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March 1974

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

Food Laboratory

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13. ABSTRACT

Laboratory tests were conducted on dehydrated soups as a result of a request by the Air Force for the development of soups for use aboard aircraft operating above 15,240 meters (50,000 feet). These tests involved storage studies on seven different commercially available soups after repacking in flexible packages under vacuum. All seven soup products were rehydratable in 65.6°C water and remained relatively stable when stored at 21.1°C for one year. All soups packed under vacuum were acceptable in all quality characteristics when stored for three months at 37.8°C. None of the soups had acceptable flavor when stored for six months and twelve months at 37.8°. Thiobarbituric acid (TBA) test data and package gas analysis information on the stored soups were obtained. Oxidation data show that the change in flavor from what may be considered acceptable to unacceptable (rating below 5.0) of all vacuum packed soup products during storage for twelve months at 37.8°C correlates well with the reduction in oxygen level in the soup package. The relationship was best represented by a first degree polynomial (linear).

Microbiological requirements have previously been established for space foods in terms of total aerobic plate counts, coliforms, fecal coliforms, fecal streptococci, coagulase-positive staphylococci and salmonella on a dry basis. All soup products rehydrated with 65.6°C water at the manufacturer's recommended level of water to solids meet these microbiological requirements.

It is concluded that there is sufficient information to warrant a limited production run and field test of six of the seven soups. The dehydrated soups recommended for this test are spring vegetable, green pea, cream of chicken, onion, chicken noodle and cream of mushroom.

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FOREWORD

The Air Force requested the development of a variety of dehydrated soup products for use aboard aircraft which operate above 15,240 meters (50,000 feet). Preliminary studies at the US Army Natick Laboratories indicated that a number of commercially available dehydrated soup products might satisfy the US Air Force requirements. In view of this, it was decided to conduct a series of laboratory storage studies on seven different types of commercially available soup products which had been repacked in flexible packages under vacuum.

This work was performed under Project No. 1G762713A04; Mr. Harold Gorfien was the Official Investigator.

The authors wish to acknowledge the assistance of the Food Laboratory's Chemistry Division at US Army Natick Laboratories: S. Bishov for recommending soup package gas analyses and M. Robertson for performing the gas analyses; and L. Cox and I. Block for conducting the TBA tests. S. J. Werkowski and L. Klarman of the US Army Natick Laboratories are acknowledged for assistance in statistical analysis of the data.

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ABSTRACT

Laboratory tests were conducted on dehydrated soups as a result of a request by the Air Force for the development of soups for use aboard aircraft operating abo e 15,240 meters (50,000 feet). These tests involved storage studies on seven different commercially available soups after repacking in flexible packages under vacuum. All seven soup products were rehydratable in 65.6°C water and remained relatively stable when stored at 21.1°C for one year. All soups packed under vacuum were acceptable in all quality characteristics when stored for three months at 37.8°C. None of the soups had acceptable flavor when stored for six months and twelve months at 37.8°C. Thiobarbituric acid (TBA) test data and package gas analysis information on the stored soups were obtained. Oxidation data show that the change in flavor from what may be considered acceptable to unacceptable (rating below 5.0) of all vacuum packed soup products during storage for twelve months at 37.8°C correlates well with the reduction in oxygen level in the soup package. The relationship was best represented by a first degree polynomial (linear).

Microbiological requirements have previously been established for space foods in terms of total aerobic plate counts, coliforms, fecal coliforms, fecal streptococci, coagulase-positive staphylococci and salmonella on a dry basis. All soup products rehydrated with 65.6°C water at the manufacturer's recommended level of water to solids meet these microbiological requirements.

It is concluded that there is sufficient information to warrant a limited production run and field test of six of the seven soups. The dehydrated soups recommended for this test are spring vegetable, green pea, cream of chicken, onion, chicken noodle and cream of mushroom.

INTRODUCTION

The Air Force requested the development of a variety of soup products which satisfy specific parameters. The soup products are to be dehydrated and flexibly packaged with a total pressure differential of one atmosphere. These dehydrated soups are to remain stable in quality and be capable of rehydration with 65.6°C water after storage for one year at 21.1°C. These items are required for use aboard aircraft with limited space and lack of refrigeration, which operate above 15,240 meters (50,000 feet).

The Armed Forces currently authorize approximately 55 soups of various types or in various packages (1). Most of these items cannot be used to satisfy the Air Force requirements, but six do have possibilities. Three are low moisture products (not more than 2.0% moisture) which require special manufacturing and handling conditions. These are: Soup and Gravy Base, instant, beef flavored; Soup and Gravy Base, instant, chicken flavored; and Soup and Gravy Base, instant, ham flavored, which are included in a Federal Specification (2) covering Bouillon. The remaining products are: soup, instant, beef; soup, instant, chicken; and soup, instant, onion, for which purchase is effected by specifying "high commercial grade" rather than by a specification.

In view of ease of availability, it was deemed that commercially available products would be relatively inexpensive compared to freeze-dried or lower moisture specification soups; and with vacuum packaging, the present industrial capability in the United States could manufacture the products for the Air Force.

The questions of ability to rehydrate at 65.6°C and stability for one year at 21.1°C remained to be answered.

PREVIOUS RELATED STUDIES

A review of the literature provided information on ingredients, manufacturing processes, quality control and packaging of soups (3). Further information on analytical methods used in the soup industry has been compiled in a laboratory manual (4).

In a study conducted in 1961 it was demonstrated that dehydrated green pea soup could be held for as long as 2 years at 21.1°C or 37.8°C and remain acceptable (5).

Studies on dehydrated cream of onion and cream of potato soups with and without vitamin fortification have been conducted (6). These soups were stored in flexible containers at 21.1°C and 37.8°C. Vitamin content and mean palatability ratings decreased during storage, but both soups were found to be acceptable after 6 months at 37.8°C and 2 years at 21.1°C.

A series of freeze-dried soups have been developed for space feeding. Manufacturing requirement documents describing the food processing and packaging technology have been included in a report published in 1970 (7). Freeze dried corn chowder, pea soup and potato soup with moisture contents not greater than 4.0% are described in the report.

A lima bean soup was developed by precooking, milling and dehydrating that resulted in a lima bean powder which rehydrated rapidly. This soup when stored in flexible packages was stable for more than six months at 37.8°C (8).

In a storage study on soup and gravy base (9) average ratings were found to vary from good to fair. Soup and gravy base quality changed little at 0°C, but at 8.3°C or 21.1°C quality changes increased. Although the broth prepared from this base was scored fair after six months at 37.8°C, examinations were discontinued at 12 months because of product darkening and caking. There was a general trend for product pH to decrease and titratable acidity to increase during storage at 37.8°C within six months. Moisture content was found to increase with time in storage. This increase in moisture was ascribed to deteriorative reactions or to increased ease of release of volatiles other than moisture.

A study was made of the effect of initial quality of rendered chicken fat on the stability of chicken-flavored soup and gravy mix (10). Stability was determined by oxidation rate studies and by a trained acceptance panel. Peroxide values of the soup and gravy base samples were found to decrease during storage at 37.8°C for 1 year. The quality of the soups did not change significantly as demonstrated by the acceptance panel. Stability of the soup and gravy mix was found to be due to the presence of hydrolyzed vegetable protein.

Fresh flavor quality was retained in a series of freeze-dried foods of plant and animal origin in "zero" oxygen headspace (11). Oxygen was eliminated by the use of an atmosphere of 5% hydrogen in nitrogen with a palladium catalyst. Beef stew and chicken stew in a "zero" oxygen environment had aroma and flavor characteristics after storage at 37.8°C for 6 months comparable to the original products. Control freeze-dried products in a 2% oxygen atmosphere took up oxygen in storage. Oxygen uptake during storage was more rapid in animal products than in plant products. Consumer test panels demonstrated a preference for foods packed in "zero" oxygen over those packed in 2% oxygen. This preference persisted throughout a 1 year storage period at 37.8°C.

METHODS AND MATERIALS

The test plan was designed to determine whether commercially available dehydrated soups which were packed under vacuum would be rehydratable in 65.6°C water and remain stable for 1 year at 21.1°C.

Seven different types of commercially available air packed soups in flexible packages were obtained. A portion of these soups was repacked under 28 inch vacuum (6,754 Pa)* using a Flex-Vac machine. These soups are (a) Spring Vegetable, (b) Tomato, (c) Green Pea, (d) Cream of Chicken, (e) Onion, (f) Chicken Noodle, and (g) Cream of Mushroom. The packaging material was composed of 0.076 mm (0.003 inch) blend of high density polyethylene and polyisobutylene, 0.0089 mm (0.00035 inch) 1145-0 aluminum foil alloy, 0.0127 mm (0.0005 inch) polyethylene terephthalate (12).

Samples of each type soup, air packed and vacuum packed, were stored at 4.4°C, 21.1°C and 37.8°C for a period of 12 months. Samples were drawn at the start, and after 3, 6 and 12 months of storage for testing of quality, incipient rancidity and oxidation. Microbiological tests were also conducted to determine general sanitary quality of the soup products.

Soup quality. - A technological panel was used to determine soup quality. The soup was rehydrated with 65.6°C water and then rated for color, odor, flavor, texture and appearance. A rating of 1 to 9 was used for each specific quality characteristic based on the following: 1-Extremely poor, 2-Very poor, 3-Poor, 4-Below fair above poor, 5-Fair, 6-Below good above fair, 7-Good, 8-Very good, 9-Excellent.

Incipient rancidity. - A modified 2-thiobarbituric acid (TBA) test was used to determine incipient rancidity (13). In this test a red color complex is formed when malonaldehyde in a rancid food is treated with an acidic TBA solution; the complex has an absorption maximum at about 532 nm.

Oxidation. - A reduction in the level of oxygen in the atmosphere present in the package of soup (oxygen uptake) during storage was used as an index of oxidation of the product. The gas chromatography method to determine composition of gases above autoxidized fat (14) was used to establish package oxygen levels.

Microbiological quality. - Microbial tests were conducted on the soup products as an indication of sanitary quality. The following microbiological tests were conducted as described in reference (15):

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* Vacuum gauge reading was converted to Pascals (Pa) by the following formula: (30 inch - Vacuum Guage reading) X 3.37685 X 10^3 = N/M^2 = Pa.

(a) Total aerobic plate count
(b) Total coliform count
(c) Fecal coliform count
(d) Fecal streptococci count
(e) Coagulase-positive staphylococci
(f) Salmonella.

These six bacteriological tests were conducted on (A) Soup powder with an initial 1:10 dilution made with 21.1°C sterile buffered water, (B) Soup powder with an initial 1:10 dilution made with 65.6°C sterile buffered water, and (C) Soup powder (stored at 4.4°C, 21.1°C, and 37.8°C for six months) which had been rehydrated with 65.6°C sterile water per manufacturer's instructions and then diluted 1:10 with 21.1°C sterile buffered water. The ratio of soup powder to water for the rehydration of each soup was as follows:

(a) Spring vegetable soup, 0.0115 kg + 160 ml 65.6°C water
(b) Tomato soup, 0.024 kg + 185 ml 65.6°C water
(c) Green pea soup, 0.035 kg + 185 ml 65.6°C water
(d) Cream of chicken soup, 0.021 kg + 160 ml 65.6°C water
(e) Onion soup, 0.0105 kg + 185 ml 65.6°C water
(f) Chicken noodle soup, 0.0125 kg + 185 ml 65.6°C water
(g) Cream of mushroom soup, 0.017 kg + 160 ml 65.6°C water.

RESULTS

Soup quality. - All seven soup products were rehydratable in 65.6°C water. Technological panels conducted on the seven soups during the year storage period demonstrated that all seven soups were liked (technological panel rating above 5.0) and therefore may be considered acceptable after storage for one year at 21.1°C. These soups were therefore relatively stable. Detailed information with respect to each quality characteristic shows the following:

(a) Color (Table 1) - At storage temperatures of 4.4°C and 21.1°C all soups had an acceptable color rating for the entire 12 month period. When stored in air or vacuum at 37.8°C only the green pea, onion and cream of mushroom soups remained acceptable for the 12 month period.

(b) Odor - No objectionable off odor was detected in any of the soups.

(c) Flavor (Table 2) - At 4.4°C and 21.1°C the flavor of all seven soups remained acceptable for the entire 12 month period. With the exception of tomato soup stored in air, all soups had an acceptable flavor when stored at 37.8°C for three months. None of the soups had an acceptable flavor after six months storage at 37.8°C.

(d) Texture (Table 3) - All soups had an acceptable texture rating for the entire 12 months period at 4.4°C and 21.1°C. At 37.8°C the green pea, onion and cream of mushroom soups remained acceptable whether stored in air or under vacuum for the 12 month period. The chicken noodle soup had to be stored under vacuum to remain acceptable at 37.8°C for 12 months.

(e) Appearance - Except for color as described previously, appearance was not seriously affected.

Incipient rancidity (Table 4) - TBA tests on the seven soup products over the 12 month period showed the following:

(a) All products stored in air at all test temperatures, except for chicken noodle soup stored at 37.8°C, had more malonaldehyde present after 12 months than at the start.

(b) All products stored under vacuum at all test temperatures, with two exceptions, had more malonaldehyde present after 12 months than initially. The exceptions to this were chicken noodle soup and cream of chicken soup at 4.4°C, 21.1°C, and 37.8°C.

(c) In general, soup products stored for 12 months under vacuum had less malonaldehyde than when stored in air for a comparable period. The exceptions to this were cream of mushroom soup stored at 4.4°C and 21.1°C and tomato soup stored at 37.8°C.

Oxidation (Table 5) - (a) When stored in air at 4.4°C and 21.1°C for 12 months there did not appear to be any large reduction in oxygen level in the soup packages. Spring vegetable soup did exhibit a reduction in oxygen level at 21.1°C from an average of 18.4% to 15.2%. At 37.8°C large reductions in oxygen level were exhibited in all soups with the exception of onion soup and cream of mushroom soup which had smaller reductions.

(b) When stored under vacuum for 12 months, the data demonstrate that increasing the temperature of storage results in an increase in oxygen removal. All soup products at 37.8°C exhibited an increase in oxygen removal with storage time.

Microbiological Quality (Tables 6 & 7) - Microbiological tests conducted on the soup powder and rehydrated soups indicated the following:

(a) Total aerobic plate count. - Total plate count ranged from 840/0.001 kg to 4720/0.001 kg for all soup powders with the exception of onion which ranged from 7760/0.001 kg to 1.6 x 10^5/0.001 kg. Rehydrated soup had total plate counts ranging from 20/ml to 1100/ml.

(b) Total coliform count. - Total coliform count ranged from <1/0.001 kg to to 4/0.001 kg for all soup powders with the exception of spring vegetable, green pea and chicken noodle which had 19/0.001 kg, 50/0.001 kg and 109/0.001 kg respectively. Rehydrated soup had <1 coliform per ml.

(c) Fecal coliform count. - Fecal coliforms in all tests were either <1/0.001 kg of soup powder or <1/ml soup.

(d) Fecal streptococci count. - Fecal streptococci count for the soup powders ranged from <1/0.001 kg to 899/0.001 kg. Rehydrated soup had <1 streptococci per ml with the exception of vacuum packed mushroom soup stored at 21.1°C which had 16/ml.

(e) Coagulase-positive staphylococci. - Coagulase-positive staphylococci in all tests were either negative in 0.005 kg or negative in 5 ml.

(f) Salmonella. - All tested samples were negative for salmonella.

DISCUSSION

All seven soup products were found to be rehydratable in 65.6°C water and to remain relatively stable for a one year storage period at 21.1°C. All soups packed under vacuum were also found to be liked and therefore may be considered acceptable in terms of all quality characteristics when stored for three months at 37.8°C. When stored for six months and twelve months at 37.8°C none of the soups retained acceptable flavor. The TBA test data on incipient rancidity demonstrate some of the oxidative changes that occurred in the soup products. The reasons for products as chicken noodle soup and cream of chicken soup testing out lower in malonaldehyde after storage under vacuum for twelve months are not known. This could be due to the antioxidant properties of hydrolyzed vegetable protein reported previously (10). Oxygen uptake data on vacuum packed soups stored at 37.8°C demonstrate that all soup products underwent oxidation. It also shows that the change in flavor from what may be considered acceptable to unacceptable (rating below 5.0) of all vacuum packed soup products during storage for twelve months correlates with the reduction in oxygen level in the soup package. A comparison of the relationship between soup flavor and oxygen uptake during storage by orthogonal polynomial analysis (16) resulted in the derivation of a relationship which best represented the data in vacuum packed soups stored at 37.8°C, Tables 2 and 5. The results are shown in Table 8. From Table 8 it was determined that the first degree polynomial (linear)Figure 1, would provide the best fit with a correlation coefficient r=.78.

Although some of the dehydrated soup products contained coliforms and fecal streptococci, the total plate counts were low and the fecal coliforms, staphylococci and salmonella were <1 or negative on a dry basis. On the other hand all soup products which had been rehydrated with 65.6°C water at the manufacturer's recommended level of water to solids on a reconstituted basis met the microbiological requirements established for dehydrated space foods (15) on a dry basis. In view of the low counts in all microbiological categories found in the rehydrated soups, it is questionable as to whether the requirements for dehydrated space foods listed under reference (15) and reference (17) should be applied on a dry basis to products which are not intended for space travel and which are to be rehydrated with 65.6°C water.

The requirements for precooked frozen meals for use by the Armed Forces for in-flight feeding are as follows: standard plate count $\leq$ 100,000 per 0.001 kg, coliforms $\leq$100 per 0.001 kg, and E. coli negative per 0.001 kg (18). It is significant that where tested all of the dehydrated soup products satisfy these requirements (18) with the exception of dehydrated onion soup; and that all of the soup products rehydrated with 65.6°C water satisfy these same requirements.

CONCLUSIONS

It is concluded that there is sufficient information available from the literature and laboratory to warrant a limited production run and field test on six out of the seven soups investigated. Tomato soup should be excluded from this test because of its lack of flavor stability when stored at 37.8°C in air for three months. Should accidental air leakage develop in a package and the product be shipped or held for a brief period at temperatures higher than 21.1°C vacuum packed tomato soup might deteriorate flavorwise prior to use. The soups recommended for this test are spring vegetable, green pea, cream of chicken, onion, chicken noodle and cream of mushroom. When packed under vacuum these six soups were found to be rehydratable in 65.6°C water and to remain stable for one year at 21.1°C. Furthermore, the ability of these products to remain stable at 37.8°C for three months both in air or under vacuum provides a reasonable anticipation of protection against deterioration should accidental air leakage develop; or if these products were to be shipped and held for relatively brief periods at temperatures in excess of 21.1°C.

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Table 1. Color Rating Changes on Soups Stored 12 Months

Storage Temperature	Type Soup	Color (Rating)* At Start	After 3 Months vac	After 3 Months air	After 6 Months vac	After 6 Months air	After 12 Months vac	After 12 Months air
4.4°C	Spring Vegetable	6.2	6.3	6.5	6.5	6.4	6.1	6.3
	Tomato	6.9	6.2	6.7	5.8	5.9	6.5	6.5
	Green Pea	7.2	6.9	6.9	6.8	6.7	7.3	7.0
	Cream of Chicken	7.1	6.3	7.2	7.0	6.8	6.5	6.4
	Onion	6.7	6.5	6.7	6.3	6.4	6.7	7.1
	Chicken Noodle	6.7	6.8	6.8	6.3	6.4	7.3	7.1
	Cream of Mushroom	7.0	6.8	6.9	6.1	6.3	6.5	6.7
21.1°C	Spring Vegetable	6.2	6.3	6.5	6.7	6.4	6.2	6.2
	Tomato	6.9	6.4	6.9	5.8	5.8	6.4	6.0
	Green Pea	7.2	6.9	6.8	6.8	6.8	7.2	6.8
	Cream of Chicken	6.7	6.8	7.1	6.8	6.8	6.8	6.5
	Onion	6.7	6.7	6.8	6.4	6.3	6.3	5.9
	Chicken Noodle	6.7	7.1	6.8	6.5	6.2	6.9	6.8
	Cream of Mushroom	7.0	6.9	6.8	6.0	6.3	6.3	6.4
37.8°C	Spring Vegetable	6.2	6.0	6.1	5.0	4.4	4.6	3.7
	Tomato	6.9	5.8	5.3	3.3	2.5	1.8	1.9
	Green Pea	7.2	6.8	6.5	6.3	6.3	5.5	5.1
	Cream of Chicken	7.1	6.3	6.5	5.3	5.8	3.5	4.9
	Onion	6.7	6.3	6.1	6.3	6.4	5.6	5.6
	Chicken Noodle	6.7	6.6	6.5	6.1	5.8	4.9	3.3
	Cream of Mushroom	7.0	6.3	6.4	5.8	6.2	5.4	5.7

vac - Vacuum packed soups
air - Air packed soups

*N = 12 (Technological Panel Judges)

Table 2. Flavor Rating Changes on Soups Stored 12 Months

Storage Temperature	Type Soup	Flavor (Rating) * At Start	After 3 Months vac	After 3 Months air	After 6 Months vac	After 6 Months air	After 12 Months vac	After 12 Months air
4.4°C	Spring Vegetable	5.9	5.8	5.8	6.5	6.4	5.8	5.8
	Tomato	6.4	6.1	6.2	5.5	5.8	6.1	5.6
	Green Pea	6.6	6.2	6.3	6.6	6.3	6.7	6.5
	Cream of Chicken	6.9	7.0	7.3	7.1	6.9	8.4	6.1
	Onion	6.3	5.9	6.2	6.3	5.8	5.9	5.3
	Chicken Noodle	6.8	6.5	6.9	6.3	6.7	6.8	6.6
	Cream of Mushroom	6.9	6.8	6.7	6.3	6.5	6.3	6.6
21.1°C	Spring Vegetable	5.9	5.8	6.2	6.7	6.3	5.9	5.5
	Tomato	6.4	6.3	6.4	6.1	5.3	5.9	5.1
	Green Pea	6.6	6.1	6.2	6.0	5.5	6.7	6.0
	Cream of Chicken	6.9	7.1	6.9	7.0	6.4	6.7	5.6
	Onion	6.3	6.0	6.5	5.6	5.3	5.3	6.0
	Chicken Noodle	6.8	6.6	6.3	6.1	6.0	6.4	5.9
	Cream of Mushroom	6.9	6.6	6.7	6.0	6.8	6.0	6.6
37.8°C	Spring Vegetable	5.9	5.0	5.1	4.3	4.3	3.8	3.1
	Tomato	6.4	5.0	4.7	3.2	2.6	2.0	1.6
	Green Pea	6.6	5.9	5.6	4.7	4.8	4.3	4.3
	Cream of Chicken	6.9	5.5	5.8	4.5	4.5	3.4	3.4
	Onion	6.3	5.8	5.8	4.8	4.5	4.5	4.5
	Chicken Noodle	6.8	5.6	5.4	4.8	3.9	4.0	2.5
	Cream of Mushroom	6.9	5.1	5.3	4.3	5.6	4.0	4.3

vac - Vacuum packed soups
air - Air packed soups

*N = 12 (Technological Panel Judges)

Table 3. Texture Rating Chages on Soups Stored 12 Months

Storage Temperatures	Type Soup	Texture (Rating) * At Start	After 3 Months vac	After 3 Months air	After 6 Months vac	After 6 Months air	After 12 Months vac	After 12 Months air
4.4°C	Spring Vegetable	6.0	5.7	5.9	6.6	6.4	6.2	6.2
	Tomato	6.4	6.5	6.9	6.0	6.1	6.5	6.3
	Green Pea	6.4	6.6	6.5	6.3	6.6	6.8	6.7
	Cream of Chicken	7.1	7.0	6.6	6.8	6.8	6.5	6.6
	Onion	6.3	6.3	6.7	6.2	6.3	6.3	6.0
	Chicken Noodle	6.3	6.7	6.9	5.6	5.8	6.8	6.8
	Cream of Mushroom	6.7	6.8	6.6	6.5	6.5	6.5	6.6
21.1°C	Spring Vegetable	6.0	5.9	6.2	6.7	6.2	6.1	5.8
	Tomato	6.4	6.7	7.1	6.1	6.1	6.2	5.8
	Green Pea	6.4	6.7	6.5	6.6	6.2	6.8	6.5
	Cream of Chicken	7.1	6.9	6.4	6.8	6.2	6.8	6.5
	Onion	6.3	6.5	6.8	6.4	6.2	5.8	5.7
	Chicken Noodle	6.3	6.8	6.8	5.8	5.4	6.5	6.4
	Cream of Mushroom	6.7	6.6	6.6	6.2	6.9	6.3	6.3
37.8°C	Spring Vegetable	6.0	6.0	5.8	4.9	5.0	4.4	3.9
	Tomato	6.4	6.0	5.9	5.1	4.5	3.2	2.1
	Green Pea	6.4	6.2	5.9	5.7	5.8	5.7	5.7
	Cream of Chicken	7.1	5.9	6.2	5.3	5.6	4.7	4.8
	Onion	6.3	6.1	6.1	6.0	6.3	5.5	5.4
	Chicken Noodle	6.3	6.2	6.3	5.1	4.8	5.0	3.6
	Cream of Mushroom	6.7	4.9	6.1	5.3	6.0	5.2	5.1

vac - Vacuum packed soups
air - Air packed soups

*N = 12 (Technological Panel Judges)

Table 4. TBA Tests on Soups Stored 12 Months

Storage Temperatures	Type Soup	TBA Test (mg malonaldehyde/kg soup) At Start	After 3 Months vac	After 3 Months air	After 6 Months vac	After 6 Months air	After 12 Months vac	After 12 Months air
4.4°C	Spring Vegetable	.36	.41	.55	.52	.57	.44	.98
	Tomato	.34	.39	.37	.49	.41	.50	.55
	Green Pea	.61	.61	.62	.59	.73	.68	.99
	Cream of Chicken	.51	.39	.46	.37	.51	.42	.57
	Onion	.35	.30	.47	.39	.37	.41	.52
	Chicken Noodle	1.11	.80	1.25	.81	1.30	1.03	1.33
	Cream of Mushroom	.12	.13	.17	.20	.21	.18	.18
21.1°C	Spring Vegetable	.36	*.84	.34	.40	.52	.40	.47
	Tomato	.34	.65	.41	.41	.37	.41	.47
	Green Pea	.61	.30	.13	.65	.72	.76	.79
	Cream of Chicken	.51	.40	.57	.45	.51	.51	.65
	Onion	.35	.43	.41	.25	.37	.48	.52
	Chicken Noodle	1.11	2.52	.68	.95	1.15	1.08	1.36
	Cream of Mushroom	.12	1.54	.17	.20	.14	.25	.20
37.8°C	Spring Vegetable	.36	.27	.78	.35	.41	.47	.58
	Tomato	.34	.51	.41	.48	.48	.50	.49
	Green Pea	.61	.66	.41	.63	.72	.64	.86
	Cream of Chicken	.51	*.60	.49	.42	.56	.47	.53
	Onion	.35	.41	.45	.30	.36	.43	.48
	Chicken Noodle	1.11	1.66	1.04	.73	1.03	.87	1.00
	Cream of Mushroom	.12	.26	.26	.29	.34	.30	.38

vac - Vacuum packed soups
air - Air packed soups

*Sample did not have good vacuum

Table 5. Oxygen Level on Soups Stored 12 Months

Storage Temperatures	Type Soup	Oxygen Level (%) At Start	After 3 Months		After 6 Months		After 12 Months	
			vac	air	vac	air	vac	air
4.4°C	Spring Vegetable	18.4	19.0	17.8	18.0	17.8	18.0	19.4
	Tomato	20.5	20.6	20.9	**	19.9	**	19.8
	Green Pea	20.6	20.8	19.8	21.1	19.7	20.8	19.7
	Cream of Chicken	20.6	**	20.3	**	20.6	**	20.2
	Onion	20.2	**	20.0	**	19.5	21.0	20.0
	Chicken Noodle	19.4	19.4	20.2	18.8	19.0	17.9	18.8
	Cream of Mushroom	20.9	**	20.8	**	20.7	**	20.8
21.1°C	Spring Vegetable	18.4	16.1	17.0	12.6	17.6	10.8	15.2
	Tomato	20.5	**	19.8	21.0	19.3	**	19.1
	Green Pea	20.6	17.8	19.3	16.1	21.1	15.4	19.6
	Cream of Chicken	20.6	**	20.4	21.0	19.5	20.0	19.7
	Onion	20.2	20.4	20.4	19.7	21.1	20.7	20.1
	Chicken Noodle	19.4	15.5	18.4	12.7	18.1	10.1	17.7
	Cream of Mushroom	20.9	**	20.7	**	20.6	**	20.6
37.8°C	Spring Vegetable	18.4	5.8	14.2	3.5	6.0	3.2	9.3
	Tomato	20.5	13.2	16.0	3.0	8.3	2.9	4.5
	Green Pea	20.6	13.5	16.2	8.2	13.6	4.9	8.5
	Cream of Chicken	20.6	12.3	19.8	2.8	15.3	8.4	11.5
	Onion	20.2	11.2	19.5	7.1	18.4	4.8	18.8
	Chicken Noodle	19.4	4.5	15.2	2.8	9.3	3.6	3.9
	Cream of Mushroom	20.9	19.7	20.5	13.1	18.4	11.6	17.8

vac - Vacuum packed soups
air - Air packed soups

**Insufficient headspace gas for accurate measurement of headspace composition

Table 6. Microbiology of Dry Soup

Type Pack	Type Soup	Total Plate Count/ 0.001 kg	Coli-forms/ 0.001 kg	Fecal Coli-forms/ 0.001 kg	Fecal Strepto-cocci/ 0.001 kg	Coagulase Positive Staphylococci/ 0.005 kg	Salmonella/0.010 kg
Air *	Spring Vegetable	3550	19	—	8	Negative	Negative
	Tomato	1950	4	<1	2	Negative	Negative
	Green Pea	1500	<1	<1	19	Negative	Negative
	Cream of Chicken	2100	50	—	90	Negative	Negative
	Onion	1.6×10^5	1	<1	67	Negative	Negative
	Chicken Noodle	4600	109	—	15	Negative	Negative
	Cream of Mushroom	2250	2	<1	83	Negative	Negative
Air **	Spring Vegetable	2540	<1	<1	118	Negative	Negative
	Tomato	1020	<1	<1	<1	Negative	Negative
	Green Pea	1000	<1	<1	<1	Negative	Negative
	Cream of Chicken	840	<1	<1	30	Negative	Negative
	Onion	7760	<1	<1	899	Negative	Negative
	Chicken Noodle	4720	<1	<1	4	Negative	Negative
	Cream of Mushroom	2060	<1	<1	77	Negative	Negative

* Rehydrated (1:10) with phosphate buffered water (pH=7.2) at 21.1°C
** Rehydrated (1:10) with phosphate buffered water (pH=7.2) at 65.6°C

Table 7. Microbiology of Rehydrated Soup

Type Pack	Type Soup*	Total Plate Count/ml			*** Coli-forms/ml	*** Fecal Coli-forms/ml	*** Fecal Strepto-cocci/ml	*** Coagulase Positive Staphylo-cocci/5 ml	*** Salmon-ella/10 ml
		4.4°C	21.1°C	37.8°C					
Air	Spring Vegetable	240	120	200	<1	<1	<1	Negative	Negative
	Tomato	40	60	100	<1	<1	<1	Negative	Negative
	Green Pea	140	140	220	<1	<1	<1	Negative	Negative
	Cream of Chicken	120	120	80	<1	<1	<1	Negative	Negative
	Onion	560	660	300	<1	<1	<1	Negative	Negative
	Chicken Noodle	140	340	120	<1	<1	<1	Negative	Negative
	Cream of Mushroom	140	120	160	<1	<1	<1	Negative	Negative
Vac-uum	Spring Vegetable	100	80	80	<1	<1	<1	Negative	Negative
	Tomato	180	40	60	<1	<1	<1	Negative	Negative
	Green Pea	200	80	20	<1	<1	<1	Negative	Negative
	Cream of Chicken	220	100	80	<1	<1	<1	Negative	Negative
	Onion	460	1100	440	<1	<1	<1	Negative	Negative
	Chicken Noodle	140	80	100	<1	<1	<1	Negative	Negative
	Cream of Mushroom	220	120	20	<1	<1	<1**	Negative	Negative

* Rehydrated with 65.6°C water; and then further diluted (1:10) with phosphate buffered water (pH=7.2) at 21.1°C.

** Less than 1/ml for samples stored at 4.4°C and 37.8°C. Samples stored at 21.1°C had 16/ml.

***Microbiological results on samples stored at 4.4°C, 21.1°C and 37.8°C.
4.4°C, 21.1°C, 37.8°C Temperatures of sample storage.

Table 8. Changes in Soup Flavor vs. Changes in Oxygen Content During Storage

Analysis of Variance for All Curves					
Variable	DF	SSQ	MSQ	F	Significance
Total	27	39.926785			
Degree 1	1	24.412323	24.412323	40.9115	S
Error	26	15.514463	.59671011		
Degree 2	1	.26058466	.26058486	.4721	NS
Error	25	15.253878	.61015512		
Degree 3	1	.79472326	.79472326	1.3191	NS
Error	24	14.459155	.60246480		
Degree 4	1	.14331954	.14331954	.2303	NS
Error	23	14.315836	.62242765		
Degree 5	1	1.1722843	1.1722843	1.9622	NS
Error	22	13.143552	.59743417		

S = Significant at the .01 level

NS= Not Significant

Figure 1. RELATIONSHIP BETWEEN SOUP FLAVOR AND OXYGEN CONTENT CHANGES DURING STORAGE